DYNAMICALLY RECONFIGURABLE PHOTOVOLTAIC SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This non-provisional application claims the benefit of the earlier filing date of U.S. Provisional Application No. 61/695,884, filed Aug. 31, 2012.

STATEMENT OF GOVERNMENT RIGHTS

[0002] This invention was developed under Contract DE-AC04-94AL85000 between Sandia Corporation and the U.S. Department of Energy. The U.S. Government has certain rights in this invention.

FIELD

[0003] An embodiment of the invention relates to energy harvesting photovoltaic (PV) power systems such as those used in spacecraft. Other embodiments are also described.

BACKGROUND

[0004] Energy harvesting PV power systems, also referred to as solar power systems, have been used to provide electric power in various applications including residences and airborne and space borne aircraft such as satellites and unmanned aerial vehicles. For residential applications, a solar panel has a relatively small number of cells where each cell is quite large, such as a silicon PV cell that may be about six inches by six inches in area, and there may be approximately 72 such cells within in a single residential solar panel. Each solar cell typically is designed to produce a certain voltage, for example, about 0.6 volts for silicon cells, which has only a weak dependence on the amount of light radiation received at the cell. Such cells may be electrically connected in series within a panel, in order to increase the harvested energy output voltage for example, 40 Volts dc (Vdc). A typical residential solar system may include several such panels, for example between five and ten, providing up to several hundred volts. A dc-ac conversion circuit is then used to obtain the more common 120 Vac output voltage.

[0005] For airborne and spacecraft applications, a PV system is used as a primary power system that feeds energy storage devices such as a battery, as well as other components of the aircraft or spacecraft such as the propulsion system. While the battery may have a relatively low voltage of less than five volts, the propulsion system may need several hundred volts at its power supply input. Accordingly, a dc-dc up converter or voltage boost circuit is used to increase, for example, a 40-volt PV output to 800 or even 1000 volts. For space applications or unmanned aerial vehicle applications, it can be seen that a power supply bus is needed that can support low, medium and high voltages depending upon the operational mode of the spacecraft or aircraft. For example, a high voltage is needed for acceleration by the propulsion unit of a satellite during orbital transfers and other maneuvers, whereas a medium voltage is needed for regular operations, and a low voltage is needed for riding out a solar storm or a safe shutdown mode. In addition, reliability, availability and maintenance needs of the spacecraft or aircraft strongly impact the design of the electrical power system, which is a critical component in such applications.

SUMMARY

[0006] An embodiment of the invention is a dynamically reconfigurable energy harvesting photovoltaic (PV) system that can produce both a low voltage and alternately a high voltage, at the same harvested energy output node, where the high voltage may be greater than the low voltage by at least a factor of ten. This aspect of the invention may help reduce the need for a separate voltage boost converter, which will help improve power efficiency in applications such as a satellite where heat dissipation may be a difficult problem. In addition, configurability enables a more efficient power receiver in cases where the incident light on the PV system is a laser beam or incoherent, not-broadband light beam from a remote source, as opposed to sunlight. When a light beam or spot "wanders" over the PV system such that a given group of cells is not illuminated continuously, it is difficult to harvest energy efficiently. An embodiment of the invention is a PV system that can adapt itself to produce a predetermined output voltage or output power level regardless of a wandering light spot.

[0007] The above summary does not include an exhaustive list of all aspects of the present invention. It is contemplated that the invention includes all systems and methods that can be practiced from all suitable combinations of the various aspects summarized above, as well as those disclosed in the Detailed Description below and particularly pointed out in the claims filed with the application. Such combinations have particular advantages not specifically recited in the above summary.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The embodiments of the invention are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings in which like references indicate similar elements. It should be noted that references to "an" or "one" embodiment of the invention in this disclosure are not necessarily to the same embodiment, and they mean at least one.

[0009] FIG. **1** depicts a reconfigurable photovoltaic system.

[0010] FIG. **2** shows a more detailed view of the photovoltaic system in one configuration, as part of a spacecraft application.

[0011] FIG. **3** shows the reconfigurable photovoltaic system in another configuration.

[0012] FIG. **4** shows a sub-array in which the cells are series-connected to each other.

[0013] FIG. **5** shows a sub-array in which the cells are connected to each in a combined series-parallel fashion.

[0014] FIG. **6** depicts a sub-array power management circuit having a dc-dc converter.

[0015] FIG. **7** depicts a cell or multi-junction power manager circuit, in block diagram form.

[0016] FIG. **8** depicts a photovoltaic cell with an associated cell or multi-junction power manager circuit in greater detail.

[0017] FIG. **9** shows how a wandering laser or incoherent light beam spot covers connected sub-arrays, while other sub-arrays outside the spot are disconnected.

[0018] FIG. **10** shows the wandering light beam spot in a different location on the photovoltaic system.

[0019] FIG. **11** illustrates various applications of the photovoltaic system.